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counties, which have been variously referred to the Permian and Trias. That this basal Permian fauna continued throughout all the time represented by 800 or 1,000 feet of deposits does not seem probable to me, and I believe yet more strongly what I always have believed, that the red beds in Kansas are Triassic in age. If they be Triassic, and corresponding to the red outcrops in the foothills in Colorado, it would seem strange that the intervening deposits between them and the Dakota, in the regions separated by only a few hundred miles, and agreeing in many lithological characters, should be in one case Cretaceous and in the other Jurassic.

GYPSUM IN KANSAS.

By G. P. GRIMSLEY, Topeka, Kan. Read (by title) before the Academy January 2, 1897.

HISTORICAL INTRODUCTION.

Gypsum (sulphate of lime), from two Greek words, *ge* (earth) and *epso* (to concoct), is a mineral that has attracted attention from very early times. The transparent variety, known as selenite, was used by the ancients as a substitute for glass in windows. The best varieties were supposed to be in upper Egypt and in Syria. It was also in favor for ornamental boxes, and for urns, in which lighted lamps were placed, and so threw a soft light through the apartments. The walls of the temple Fortuna Seia were made of compact gypsum, and the interior, though without windows, is described as "sufficiently lighted by rays transmitted through the semi-pellucid walls." The writings of Theophrastus show that the Greeks were familiar with the use of plaster of Paris, made from calcining the gypsine stone in making casts. The term "alabaster" is commonly noted in the ancient writings, and sometimes refers to compact gypsum and sometimes to the stalactite carbonate of lime, so that it is often difficult to tell from the meager descriptions which is intended.

The earliest account of the use of gypsum as a fertilizer in the ground form known as land plaster is in 1768, when a German clergyman, by name of Mayer, used it with success. After this time there were numerous experiments made to test its efficiency, and the faith of the workers along this line gave the appearance of wonderful results. Thus, one writes that "the invariable results of several experiments incontestably prove that there is a most powerful and subtle principle in this tasteless stone, but by what peculiar agency or combination it is capable of forcing vegetation in such an instantaneous and astonishing manner is a mystery which time reserves for others to unfold."

VARIETIES.

Gypsum in nature occurs in five forms, all of which are found in Kansas:

1. The earthy form, yellow or gray in color, and composed of loose, dust-like particles, rather light in weight, and formed from solution of gypsum in water.
2. The compact variety, including alabaster and massive gypsum, which is very soft and of specific gravity 2.2 or near.
3. Fibrous gypsum or satin-spar, usually found in thin layers, in the form of fine needles or prisms.
4. Foliated gypsum, sometimes massive, but usually in small concretionary masses.
5. Spar gypsum or selenite, found in transparent crystals.

WHERE FOUND.

Gypsum is found in Thuringia, Saxony, Norway, at Mont Martre, near Paris, in Austria, Bohemia, Italy, Egypt, Arabia, Persia, and many other places in the old country. In the United States it is found along an east and west line in cen-

tral New York, from Oneida county to Niagara; near Sandusky, Ohio; near Grand Rapids and Alabaster point, Michigan; in Smyth and Washington counties, Virginia; in Alabama and Louisiana; in Iowa, Kansas, Arkansas, Texas, Oklahoma, Indian Territory, Colorado, Montana, Utah, South Dakota, Wyoming, Arizona, Idaho, New Mexico, California. The total amount produced in the United States in 1894 was 239,312 short tons. The state of Kansas* produced that year 64,889 tons, of which all but 647 tons was calcined, thus standing second to Michigan among the states in quantity mined. The value of this product was \$301,884, an excess of \$112,264 over Michigan, placing this state first among the states of the union in value of gypsum products. The value of Kansas gypsum mined that year was greater than that of all the other states, excepting Michigan. There has been an increase in the value of the gypsum products of Kansas of \$207,649 in six years, which makes a record the state may well be proud of, and at the present time a very small percentage of the available supply has been taken, so that Kansas gypsum has a promising future.

LOCATION AND DIVISION OF AREA.

The gypsum deposits of Kansas occur in a belt trending northeast-southwest across the state. The belt of exposed rock varies in width from 5 miles in the north to 14 miles in the central part and 36 miles near the southern line, with a length of 230 miles.

This area is naturally divided into three districts, which are named from the important centers of manufacture: the northern or Blue Rapids area, in Marshall county; the central or Gypsum City area, in Dickinson and Saline counties; the southern or Medicine Lodge area, in Barber and Comanche counties. These areas appear to be separate; but careful mapping shows a number of isolated intermediate deposits which serve to connect at least two of the larger areas. Gypsum is reported from near Randolph and in the reservoir excavation at Manhattan, in Riley county. It is worked for plaster at Longford, in the southern part of Clay county; and it is found near Manchester, in the northern part of Dickinson county. These smaller areas indicate a connection between the northern and central areas.

Gypsum deposits of economic importance are reported from near Peabody, in Marion county, while they appear to be absent through Reno, Sedgwick, and Kingman counties, where the extensive salt deposits occur. There is thus a break between the central and southern areas which is occupied by salt deposits.

GEOLOGY.

The northern area is located in the Permian beds, consisting of fossiliferous limestones and shales. The central area lies in the Permian, though higher than the northern, while the salt measures to the south occur near the top of the Permian. The southern Kansas gypsum is found in a series of red, sandy shales, called the red beds, which probably mark the transition from the Permian to the Cretaceous. The deposits therefore rise geologically from north to south, but they are confined to the Permian formation. The deposits to the south in Oklahoma and Texas are placed in the Permian, while those at the north in Iowa are referred to the Cretaceous.

TOPOGRAPHY.

The northern area shows the remnant of a plateau of 1,250 feet elevation, now indented by the Blue rivers and their tributaries, yielding a somewhat rugged topography. The central area lies 70 miles southwest of Blue Rapids. The

* Statistics from Sixteenth Annual Rep. U. S. Geol. Surv., 1896.

area is drained by the Smoky Hill river, which flows in an extremely irregular or winding channel north of east, uniting with the Republican at Junction City, 30 miles away, to form the Kansas. It flows in the middle of a broad valley, 1,100 feet above sea-level and a mile or more in width. Its tributaries in the gypsum area are three or four small creeks—Gypsum, Holland, and Turkey—which flow almost directly north. The main watershed lies 22 miles to the south of the river, and trends nearly east and west, with an elevation of 1,500 to 1,550 feet. This descends on the south side within eight miles to 1,400 feet at the Cottonwood river. The divides between the north-flowing creeks have a gradual slope of about 20 feet to the mile, and their sides are deeply indented by erosion. They vary in height above the creek level from 100 to 150 feet. The effect is that of a dissected plateau with irregular surface. A number of small towns are situated along the railroads in the central part of the area, while the larger cities are located on the river.

The southern area is situated 120 miles southwest of Gypsum City. The northern part is drained by the Medicine Lodge river, which rises in Kiowa county and flows southeast to Medicine Lodge, where it abruptly turns south and flows into Oklahoma. There it empties into the Salt Fork of the Arkansas river. The southern part is drained by the Nescatunga and its branches. The streams have cut deep channels or cañons in the soft strata which reach 200 feet in depth. The watershed between the two rivers is broad in Comanche county, with an elevation of 2,200 feet, but it rapidly narrows to the southeast, in Barber county, where its elevation is 2,000 feet, descending to 1,600 feet in the valley of the Medicine Lodge river within a distance of seven miles. The watershed trends parallel with this river and turns south near the central part of Barber county, still parallel with the river. This region, with its gypsum-capped buttes of red clay and shale, possesses a very rugged topography and gives evidence of great erosion. These features are well shown in photographs of Flowerpot mound, and also in photographs of the gypsum hills near the town of Medicine Lodge.

BLUE RAPIDS AREA.

The first gypsum deposits worked in the state of Kansas were in the northern or Blue Rapids area. In November, 1869, the county commissioners laid out the site for the town of Blue Rapids. They carefully investigated the natural resources of the region and recognized the value of the water-power of the Blue, and also the value of the gypsum deposits which had been known for some time to exist on the Big Blue about two miles northwest of the town. On selling their various properties they made a reservation along the Blue of 100 rods, including the known outcrop of the beds and extending back from the river for a distance of 320 feet.

About the year 1871, Mr. J. V. Coon, of Elyria, Ohio, came to the new town, and, the story goes, he burned some of the gypsum and carried it back to Cleveland, where it was pronounced to be of good quality, and two car-loads were ordered at a good price. He and a brother returned to Blue Rapids in 1872 and built a frame shed on the east bank of the river, below the town. In an iron kettle, which held about five barrels, and which was heated by a stove, they commenced the manufacture of plaster of Paris. Prosperity seems to have attended their work, for in 1875 a stone mill was built by Coon & Son on the west bank of the river, and the water power of the river was now used for grinding. This mill is now standing—a monument to the commencement of a great Kansas industry. The town, for the purpose of encouragement of the new departure, granted them the north half of their reservation, described as extending from a

point at the middle of the outcrop and thence north. This mill was operated for nearly 12 years, when the firm unfortunately failed. The mill property and the gypsum grant of 50 rods of outcrop and 20 rods back in the hill, came into the hands of Mr. Sweetland, a business man of Blue Rapids. It was leased to several parties, and the mill was run till the year 1889, when flood caused considerable damage, resulting in the abandonment of the mill.

Mr. Hayden, of New York, in 1887, bought the remaining portion of the old reservation and the adjoining Robinson farm. Fowler Bros. bought the farm back of the Sweetland 20-rods limit.

The earlier mining was done by stripping the cover of dirt and shales, and the rock was hauled in wagons to the mills. Later it was brought down the river in flat-boats drawn by a small steam tug.

In 1887 the Fowlers formed the Blue Rapids Plaster Company and built a one and one-half story frame mill, of one-kettle capacity, on the west side of the river, at the edge of the town. The present entry to the mine is 15 feet above the water level, though the gypsum bed-rock is the bed-rock of the river, which is four feet deep at this place. The entry runs east about 350 feet, and the gypsum dips west toward the river. Five men are employed at the mine, and the rock is hauled out and up an incline to the railroad, where a 25-ton car is loaded in two days and hauled to the mill. The gypsum occurs as a gray, mottled rock, with sugary texture, breaking with irregular fracture. The top consists of white selenite needles forming satin-spar, with a thickness of $\frac{1}{4}$ to $1\frac{3}{4}$ inches. Throughout the mine are numerous cutters, in which are found perfect transparent crystals of gypsum, usually of small size.

The Great Western mine is located on the side of a bluff, one mile north of the town and 45 feet above the level of the water in the river. It is $2\frac{1}{4}$ miles south-east of the Fowler mine. The entry runs east of north about 400 feet. In the first 200 feet the gypsum is in rounded masses, thick at the middle and running out on the sides, with the trend across the entry and parallel with the slope of the hill. These appear to be old water-courses. The thickness of the gypsum layer is the same as at Fowler Brothers' mine, $8\frac{1}{2}$ feet, and both rest upon a limestone floor. The gypsum rock resembles very closely that already described, except there is an absence of cutters and crystals.

On the banks of the Little Blue, two miles west of town, is located the Winter mine. The entry runs east, and is in the hill about 900 feet. The rock does not differ in appearance from other parts of this area.

These three places are the only ones in the northern area where the rock is used; but it outcrops at a number of other localities, and is struck in the various wells to the north, south and west of Blue Rapids; but it appears to be absent in the wells to the east.

GYPSUM CITY AREA.

In the northern part of the area, six miles southwest of Solomon City, on Gypsum creek, is located the mill of the Crown Plaster Company. The workable stratum of gypsum is five feet, and is covered by 40 feet of shale and gypsum layers, which are much folded and broken. The entry is 20 feet above the water in the creek, and is driven 115 feet east, with two north entries 80 feet in length. The upper part of the stratum is similar to the northern gypsum, but the lower portion is very compact, and is dotted with elliptical crystals of yellowish-brown selenite, with the greater length in the direction of the vertical crystal axis. The crystals are nearly one inch long and one-half inch wide, and give an appearance somewhat of the bird's-eye limestone of the eastern United States.

At Hope, 20 miles southeast, is located the only other mine in the rock gyp-

sum in the central area. This is owned by the Kansas Cement Plaster Company, and they now obtain the rock from a 14-foot stratum at the bottom of an 80-foot shaft. This rock is white, and much of it is traversed by wavy, dark lines, which give a gneissoid appearance, and the plaster made from it is sold under the name of "granite cement plaster." The lower part is compact, and contains the rounded crystals of selenite, as in the mine at the north. Through this region there is another stratum, five feet in thickness, and 100 feet higher, but it is not worked at the present time.

SECONDARY DEPOSITS.

Most of the plaster mills of the central area use the earthy gypsum deposits, which occur at various places in the region. There are five of these known. The first of these was discovered in the spring of 1873, near Gypsum City, by Mr. John Tinkler, in running a fire-guard around a field. Two years later he calcined some of the dirt, as it is locally called, in an ordinary 38-gallon kettle and used the plaster in the cellar of his house, where it still remains in good condition. In 1889, he, with others, built a mill at the edge of town, but it is no longer used. The deposit covers an area of 12 acres, with an average thickness of eight feet. It consists of a loose, granular dirt, of light ash-gray color when dry, and is readily shoveled into cars. It is thus directly calcined with less labor and expense than is the case with the solid gypsum rock.

A number of years after the discovery of this deposit, Mr. Gotlieb Heller discovered a similar deposit 14 miles east, near Dillon station. Another deposit is located $3\frac{1}{2}$ miles southwest of Dillon, and is five feet thick. In Marion county, about six miles south of the last deposit, the Acme Company own a mill and similar deposit which is 6 to 10 feet thick. The Agatite Company have another mill and deposit at Longford, in Clay county, 35 miles northwest of the Dillon mill.

All of these deposits lie in low, swampy ground, and strong gypsum springs are usually found in them. In most, there is a ledge of rock gypsum at the same level or 10 to 20 feet below. The presence of recent shells and bones near the bottom of these deposits shows they are recent in age.

MEDICINE LODGE DEPOSITS.

The southern Kansas gypsum, with its continuation in Oklahoma and Texas, forms the largest area in the United States. Near Medicine Lodge the rock caps the hill as a layer 25 feet thick, protecting the underlying soft red beds, thus causing the very rugged topography already described. The red clays and shales below the gypsum contain interlacing network of selenite and satin-spar layers which have been dissolved out of the solid stratum and carried down by circulating water. In the western part of the area solution has carved out caves and underground channels, leaving, in many places, natural bridges of gypsum. The rock is snowy white, and the greater portion has a sugary texture, though the lower portion is compact. There are two mills making plaster of this rock. Best Brothers own a mill at the town of Medicine Lodge and manufacture the product known as Keene's cement or Robinson cement. This mill has been in operation since 1889. The Standard Cement and Plaster Company have a mill west of Sun City and manufacture about 18 tons of plaster per day. This great gypsum area is practically undeveloped at the present time.

ORIGIN AND AGE.

I have treated this subject quite at length in a recent paper for the "Bulletin of the Geological Society of America," which will soon be issued from the press. The central and northern rock strata were deposited in an arm of the sea, cut off from the main ocean in the lower Permian or Neosho epoch. Farther out in the

old gulf salt was deposited in large amounts, and forms to-day an important addition to the mineral wealth of the state. No salt is now found close to the gypsum, and if it did exist it has been removed by solution. The irregular upper surface of the gypsum shows that there has been solution in some places where large quantities of gypsum rock have been carried away.

The swamp deposits of earthy gypsum have probably been formed by deposits from springs, aided by wash from the hillsides, and they are recent in age.

The southern gypsum was deposited in a shallow gulf cut off not far from the close of the Permian time. As in the northern gulf, a salt deposit occurs to the southwest in the salt-plains district; but no trace is found near the gypsum.

THE STUDY OF NATURAL PALIMPSESTS.

By G. P. GRIMSLEY, Topeka, Kan. Read (by title) before the Academy January 2, 1897.

Paleontology has revealed a long life-history from Cambrian time to the present, and has vainly attempted to read the obscure pages of earlier history of Archæan time. Baffled at every turn, the search was abandoned; but a new science has boldly entered the field, and the mysterious pages furnish a history for the petrographer, which in interest rivals that of the paleontologist.

This record is not written in fossil letters, but in mineral characters, which so long have been meaningless geoglyphics. In making the so-called prehistoric record, nature has been economical in materials and in space. She has erased some portions of the ancient record with the cleansing force of fire, rewriting on the same tablets of stone the records of new conditions.

The discovery that many of the records of ancient historical time were written on erased parchments of an earlier day, and that a careful investigation would reveal many of the first records, was a historical triumph. The students of ancient languages have enriched the world by their painstaking search through old literary palimpsests. In the past decade the students of nature have discovered the existence of *natural palimpsests*, and they are now endeavoring to read the imperfectly erased records of the past, and thus add new chapters to the history of the earth. To the process of erasure and rewriting these investigators have given the name *metamorphism*; and the natural palimpsests are called *metamorphic rocks*.

The studies of biologists have shown that throughout organic nature there is a most delicate adjustment to environment. The researches of petrographers have shown that in the inorganic world minerals are so delicately adjusted to surrounding conditions that changes in the latter are recorded by variations in the minerals. The recognition of this fact in recent years is the foundation of the new knowledge concerning the Archæan period.

According to the Wernerian theory of the last century, crystalline rocks were deposited as chemical precipitates from a primeval heated ocean before life existed. They were produced at their origin as they exist to-day. Near the close of the century, Hutton found granite dikes penetrating other rocks, thus proving an igneous origin. He then advanced farther and formed the interminable cycle, stating that rocks were decomposed by atmospheric action, the detritus accumulated at the bottom of the sea, where under the pressure and heat it was rendered crystalline, and later elevated to pass through the same series of changes without trace of beginning or prospect of end. The theory of the transformation of rocks under heat and pressure originated at this time in this rudimentary form in Scot-